

3.8 WATER RESOURCES

The ocean surrounding the Hawaiian islands receives 25 to 30 inches of rainfall per year. The islands receive 10 to 15 times as much in some places. The maximum rainfall occurs at elevations between 2,000 to 3,000 feet (610 to 915 meters). Above this elevation, rainfall decreases rapidly, so that the high elevations are relatively dry. The prevailing winds are northeasterly trade winds, so that for most of the year, the maximum rainfall occurs on the eastern, or windward, sides of the islands. The western, or leeward, sides of the islands, being in the shadow of the higher mountains, receive far less rainfall. Thus, rainfall is very unevenly distributed on the islands.

On O‘ahu, the watersheds are small, with little storage capacity, causing rapid runoff and common flooding. Streams on O‘ahu are generally perennial (year-round) at higher elevations, where there is greater precipitation, and at lower elevations, where the topography intercepts the groundwater table and causes springs. At intermediate elevations, streams tend to be intermittent where the high infiltration rate soils absorb the higher elevation runoff. On the island of Hawai‘i, there are few defined watersheds because the young highly permeable rock and soil deposits generally absorb the precipitation without forming stream channels. The exception is along the island’s northern coast, where at least one perennial stream, and better defined intermittent streams are found.

The groundwater resources on O‘ahu are well developed, yielding over 635 mgd (2.4 billion liters per day) from numerous hydrogeologic units and aquifer basins. Approximately 50 percent of the fresh water used in Hawai‘i, and about 99 percent of the drinking water, is from groundwater, O‘ahu is more dependent on groundwater than the other islands. In 1975, groundwater accounted for about 85 percent of the water used for municipal, industrial, agricultural, and military uses.

3.8.1 Introduction/Region of Influence

The ROI for surface water resources includes the watersheds containing SBCT training and deployment areas on O‘ahu and Hawai‘i. The ROI for surface water is not necessarily the same as the ROI for groundwater. Because groundwater often crosses topographic (watershed) boundaries, the ROI for surface water is expanded to include the aquifers underlying these watersheds and any aquifers downgradient (in the direction of groundwater flow) from the training and deployment areas. The ROIs for both surface water and groundwater include the downstream and downgradient nearshore areas along the coast where surface water and groundwater, respectively, discharge to the sea. The ROIs for each of the SBCT training and deployment areas are identified in the following section. Federal, state, and local laws and regulations pertaining to water resources are included in Appendix N.

3.8.2 Resource Overview

Climate

The prevailing winds in the Hawaiian Islands are northeasterly trade winds during the summer and lighter southeasterly winds during the winter. Rainfall in the Hawaiian Islands is highly dependent on elevation. For example, on O‘ahu, the ridge of the Ko‘olau Range

receives about three times the rainfall as the ridge of the Waiʻanae Range (Figure 3-5). Coastal areas receive the least rainfall, and the leeward coast receives less than half as much rainfall as the windward coast. The central plateau area receives between 50 and 150 inches (127 and 381 centimeters) per year, with the highest rainfall occurring on the east side.

The highest rainfall is produced by cold fronts and Kona storms, which occur during the wet season, from October through April (Wu 1967). During the summer, tropical storms sometimes produce intense local rainfall.

Watersheds and Drainage Patterns on Oʻahu

The uneven distribution of rainfall has implications for surface water runoff and groundwater recharge. The upper portion of each watershed can receive significantly more rainfall in a given storm than the lower portion. Many of the watersheds on the islands are small (less than 5 square miles [13 square kilometers]) and there is often little storage capacity in the watershed, so runoff is usually quite rapid. The peak stream discharge from a given high intensity storm event typically occurs within one hour of the onset of the event (Wu 1967). Flash floods are not uncommon, and some streams have flood warning systems to alert hikers and others.

Surface water drainage is defined by watershed boundaries, which need not coincide with groundwater aquifer boundaries (Yuen and Associates 1990). Many of these watersheds are composed of smaller watersheds. The top of Figure 3-6 shows the major topographic division of Oʻahu, which defines the major runoff areas. Figure 3-7 shows the current watershed divisions recognized by the State of Hawaiʻi.

Many streams are perennial at high elevations, where precipitation is higher, intermittent at middle elevations, and perennial again near the coast, where the stream intercepts a shallow water table (Nichols et al. 1996). The intermittent reaches may be due to a combination of high infiltration, diversion of the flows, and high evaporation rates at low elevations. Hawaiian clay and silty clay loam soils are reported to have unusually high infiltration rates, perhaps higher than some sandy soils found on the continental US (Wu 1967). This may be due in part to the soil structure and formation of cracks that absorb moisture rapidly.

Watersheds and Drainage Patterns on the Island of Hawaiʻi

The permeability of the young volcanic deposits on the island of Hawaiʻi is very high. As a result, little or no runoff occurs and channels are not well defined, except along the northern windward coast of the island. Stearns (1966) reported that there are no perennial streams along the entire 240-mile (386-kilometer) coastline running clockwise from the Wailuku River near Hilo to the north side of Kohala Mountain. Hawaiʻi is updating its classification of streams on the island and has produced a preliminary map of the northern half of the island of Hawaiʻi that shows only one perennial stream in the ROI of the project. This is Waikoloa Stream, which heads in the Kohala Mountains north of Waimea and runs along the foot of Kohala Mountain, parallel to State Highway 19, and discharges into Kawaihae Bay, south of Kawaihae Harbor, through the Waiʻulaʻula Gulch (State of Hawaiʻi 2002b). The proposed PTA Trail route crosses Waikoloa Stream near the rock wall south of Highway 19, in the upper reach of Waiʻulaʻula Gulch.

Figure 3-5
Average Annual Precipitation on O‘ahu

Figure 3-6
Major Hydrologic Divisions on O‘ahu

Figure 3-7

Watershed Units on O‘ahu

Groundwater on O‘ahu

There are few permanent surface water resources in Hawai‘i. Ninety percent of the fresh water used on O‘ahu in 1980 was groundwater. Of this, about 81 percent is derived from volcanic rock aquifers. The long-term potential yield of groundwater systems on O‘ahu is estimated to be 480 to 635 MGD (1,829 to 2,419 million liters per day) (Nichols et al. 1996). Figure 3-8 shows the division of O‘ahu into hydrologic units (groundwater divisions) recognized by Hawai‘i and the estimated sustainable (or developable) yield (water that can be withdrawn over the long term without significant effect) of each of the hydrologic units. Figure 3-9 shows a more schematic version of this map and the general direction of groundwater flow within and between the hydrologic units. Local groundwater flow patterns may vary somewhat from the regional pattern due to local pumping influences or other local conditions.

Figure 3-10 is a generalized cross-section illustrating the occurrence of groundwater beneath the island. A “basal lens” of fresh groundwater is present in the permeable rocks beneath the island. This freshwater lens overlies seawater, because the fresh water is less dense than seawater. The top of the basal lens is usually relatively flat and typically rises inland at a rate of about 1 to 2 feet per mile (0.19 to 0.38 meters per kilometer). Thus, the top of the basal lens tends to be within an elevation range of 10 to 40 feet (3 to 12 meters) above sea level (Nichols et al. 1996). The basal freshwater lens also is called the Ghyben-Herzberg lens, after an equation of that name that relates the change in freshwater hydraulic head to the change in saltwater head. According to the Ghyben-Herzberg relation, a decrease of one foot (0.3 meter) in the thickness of the freshwater lens (such as would occur from pumping a well) will result in a corresponding 40-foot (12-meter) increase (intrusion) in the head of the salt water that it is floating on. This means, for example, that if the basal lens is at an elevation of 5 feet (2 meters) above sea level, then it extends to a depth of 200 feet (61 meters) below sea level, and if the top of the basal lens is reduced by one foot (0.3 meter), seawater would rise 40 feet (12 meters) higher beneath it. Except in areas where the fresh water is confined by an overlying impermeable formation, the basal lens thins near the coast, where it discharges to and mixes with seawater. The US Geological Survey, in cooperation with the Honolulu Board of Water Supply, drilled 12 exploratory wells in the north-central O‘ahu area in 1993 and 1994 to explore the occurrence of groundwater and to identify the depths of groundwater zones. One of the wells, located about two miles northeast of the town of Hale‘iwa in the Kawaihoa groundwater area, was drilled to 392 feet (119 meters) below mean sea level (Presley and Oki 1996).

Since the basal lens thickens rapidly inland, it would be preferable to drill wells as far inland as possible. However, in many areas the land surface rises rapidly inland, so that the depth to the basal lens also increases rapidly inland. The cost of drilling a deep well through hard rock can be high. Developers of water supplies on the islands have addressed this problem by excavating a shaft from an accessible location near the coast to the top of the basal lens, then tunneling inland as far as needed just above the basal lens, then sinking a well to tap the basal lens. These tunnels are known as “Maui” or “Lana‘i” style wells.

Figure 3-8

Groundwater Hydrologic Units and Estimated Sustainable Yields on O'ahu

Figure 3-9

Regional Groundwater Flow Patterns on O‘ahu

[Figure 3-10](#)

Generalized Cross-Section Showing Groundwater Recharge and Flow Patterns on O‘ahu

Although most basal groundwater in sedimentary deposits in coastal areas is unconfined and occurs in the upper portion of the coastal aquifers on the north and south coasts, caprock overlying the basal lens maintains confining pressure in the aquifer, increasing the thickness of the basal lens there. Historically, wells in these areas have been artesian (flowing to the surface) because of the confining pressure. The confining pressure is caused by groundwater recharge in inland areas that flows downward to the water table. At the water table, the basal lens is relatively horizontal and flows seaward through permeable strata, such as clinker beds, fractured lava flow surfaces, lava tubes, and near the coast, porous limestone deposits and sand beds. If the rock above these permeable strata is not very permeable, and the groundwater does not discharge fast enough, then pressure builds up in the aquifer. Under these conditions, if a well were drilled in the pressurized strata, the groundwater would rise in the well. In some cases, the pressure is sufficient to cause the groundwater to flow freely at the surface (an artesian, or flowing well).

Fresh water also occurs at higher elevations in perched aquifers and in dike-impounded zones, both of which are classified as “high-level” groundwater. Dike-impounded water is groundwater trapped behind vertical dikes. Dike-impounded groundwater commonly is found at elevations above several hundred feet, especially in rift areas where dikes are concentrated and rainfall tends to be higher. Perched aquifers are saturated permeable layers or fractured zones that occur above the basal lens and are separated from it by unsaturated deposits. The perched water is prevented from flowing downward to the basal aquifer by an impermeable or low-permeability zone.

Groundwater on the Island of Hawai‘i

Because of the younger age of the island of Hawai‘i and continuing volcanic activity, and the greater thickness of the volcanic deposits, groundwater occurrence on the island of Hawai‘i is not well studied. The rock at depth beneath the island is very hot, and this has enabled the development of geothermal resources. At the Puna Geothermal Site, for example, near the town of Pāhoā, southeast of Hilo, surface water is injected through deep wells to an injection zone approximately 3,900 to 7,300 feet (1,189 to 2,225 meters) below ground surface (bgs) (USEPA 2002a). Fresh groundwater that is used as a drinking water source is reportedly present at depths between approximately 600 to 2,000 feet (183 to 610 meters) bgs. The elevation of the ground surface in this area is about 650 feet (198 meters), so the fresh groundwater zone extends from just above sea level to nearly 1,500 feet (457 meters) below sea level. This is consistent with the occurrence of basal groundwater on O‘ahu.

Near the coast, where the ground surface elevation is lower, it is economical to install wells. However, in the central portion of the island, the depth to basal groundwater, if it occurs there, would make the cost of extracting the water prohibitive. West of PTA, on the convergent slopes of Mauna Loa and Hualālai Volcano, is the deepest drinking water supply well on the island. It is possible that high level groundwater occurs in some areas, impounded by vertical intrusions of magma called dikes, that can act as groundwater barriers. Alternatives to groundwater include springs, rainwater collection systems, tunnels and pipelines to convey water from watersheds with adequate water supplies to those without, and trucking of water.